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THE EFFECT OF CONTAMINANTS ON THE MAGNESIUM-SODIUM NITRATE SYSTEM

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THE EFFECT OF CONTAMINANTS ON THE MAGNESIUM-SODIUM NITRATE SYSTEM

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ABSTRACT

Sodium nitrate was "doped" with 74 contaminants. The "doped" sodium nitrate was then used to prepare miniature magnesium-sodium nitrate candles. Data was obtained on burning time, relative candlepower output and spectral distribution of the energy radiated over the region from 200 $m\mu$ to 780 $m\mu$. Evaluation of the data indicates that some dopants have advantageous effects upon the magnesium-sodium nitrate system.

I. BACKGROUND

Chemicals used in the production of military pyrotechnics are usually purchased under existing military specifications. It is the general trend of these specifications to spell out average particle size and purity of the raw materials as the most important properties of that material.

As many experienced pyrotechnicians know, a material may meet the required specification but fail to perform correctly. This knowledge has led the scientist to dwell deeper and deeper into the properties of materials and their effect in a solid-solid reaction.

This study is part of a continuing effort to investigate and determine the properties of raw materials which control their behavior in a solid-solid reaction. There could be two approaches to this problem. One being a straight analytical approach in which all the possibly known properties of the material could be correlated to the performance, or contaminants could be added to raw material and deviations in performance analyzed. Since lattice defects are one of the major rate controlling properties of a material, the latter approach was used.[1] The effect of contaminants on hygroscopicity and thermal decomposition of sodium nitrate has already been reported.[2,3]

II. INTRODUCTION

Sodium nitrate was "doped" with 74 contaminants. The only selection criteria used was that the dopant material be soluble or dispersible in water. The dopants can be placed into three categories: cation, anion, and cation-anion.

The dopants could have been incorporated into the sodium nitrate lattice as interstitial cations or cation vacancies; as interstitial anions or anion vacancies; or a mixture of both.

III. EXPERIMENTAL PROCEDURE

A. "Doping" of Sodium Nitrate

Sodium nitrate was dissolved in distilled water in the proportion of 180 grams of sodium nitrate to 100 ml of water. The contaminant material was dissolved or dispersed in a minimum amount of distilled water and added to the sodium nitrate solution. The solution was then subjected to a water bath at 0°C for 10 minutes and the sodium nitrate crystals collected and dried. The dopant concentration added was five percent by weight of the sodium nitrate.

B. Candles

Two small experimental candles from each of the contaminated samples of sodium nitrate were prepared using the following formulation:

Gram 16 atomized magnesium	57.0%
Doped sodium nitrate	38.0%
Binder (Laminac-Lupersol)	5.0%

The candles were pressed in three 30 gram increments at 7,500 psi.

C. Spectral Equipment

A Perkin-Elmer 108 scanning spectrometer was set approximately 29 inches from the burning candles, and the output recorded on magnetic tape. Spectrograph A was a Bausch and Lomb spectrograph loaded with Plus Pan-X film. Spectrograph A was set approximately 28 inches from the burning candles, and the exposure time was 10 seconds. Spectrograph B was also a Bausch and Lomb spectrograph loaded with HSIR film. Spectrograph B was set approximately 32 inches from the burning candles, and the exposure time was 5 seconds.

D. Photometric Equipment

Photocells were placed at four equal intervals around the burning candle, and they were hooked up to an electronic integrator which displays relative integrated numbers.

IV. DISCUSSION OF RESULTS

A. Relative Candlepower

Tables 1, 2, and 3 show the average burning time and average relative candlepower for the cation, anion, and cation-anion dopants, respectively. In most cases, the addition of a dopant decreased the burning time and the relative candlepower. The average burning time for a control candle was 13 seconds, and the average relative candlepower was 6.58. However, in Table 1, magnesium nitrate, thorium nitrate, iron nitrate, dysprosium, and yttrium nitrate exhibited relative candlepower which was higher than the control candles with approximately the same burning time.

In Table 2, the anion dopants, sodium peroxide, sodium sulfite, and sodium borate exhibited higher relative candlepower; and in the case of peroxide and borate, the burning time was longer.

For cation-anion dopants, boric acid and stannic chloride exhibited higher relative candlepower and no decrease in burning time.

B. Spectral Distribution

Figure 1 shows the spectral distribution in the visible region from 380 mμ to 780 mμ for a control candle and dopant candles aluminum nitrate, sodium peroxide, and cadmium nitrate. The major difference in the distribution occurs in the 530 to 630 mμ region.

The other dopant candles exhibited no noticeable difference in visible distribution.

In the region from 200 to 400 mμ there was no noticeable difference between the dopant candles and control candles. A typical distribution in this region is shown in Figure 2.

No meaningful data was obtained from the film exposed on Spectrograph A or B.

V. CONCLUSIONS AND FUTURE PLANS

Some dopant materials appeared to enhance the magnesium-sodium nitrate system. A new supply of doped sodium nitrate is being prepared for further study. The dopants to be studied further are those mentioned in the discussion of results.

A helium neon laser will be utilized to line-up the spectral equipment for the next set of experiments, since some of the monochromatic data may be questionable due to possible improper alignment.

A different formulation will be used to obtain data which will be more applicable to the four inch diameter candles now used in production.

REFERENCES

1. Garner, William E., *Chemistry of the Solid State*, Butterworths Scientific Publications, London, England, 1955.

2. Ripley, William, *The effect of Selected Contaminants on the Hygroscopicity of Sodium Nitrate*, RDTR No. 140, 7 March 1969.

3. Ripley, William, *Differential Thermal Analysis Thermograms of Sodium Nitrate Doped with Selected Contaminants*, RDTR No. 143, 12 May 1970.

TABLE I

CATION DOPANT

Dopant	Average Burning Time	Average Relative Candlepower
Magnesium Nitrate	13.5	7.23
Barium Nitrate	11	5.63
Lead Nitrate	11	5.81
Ammonium Nitrate	11	6.12
Silver Nitrate	11	4.58
Lithium Nitrate	10	5.47
Zinc Nitrate	11	6.39
Mercury Nitrate	11	5.78
Nickel Nitrate	11.5	6.79
Thorium Nitrate	12.5	7.21
Manganese Nitrate	10	4.90
Cerium Nitrate	12	6.32
Chromium Nitrate	12	6.05
Cobalt Nitrate	10.5	5.31
Aluminum Nitrate	13	6.45
Iron Nitrate	14	7.56
Bismuth Nitrate	11	5.53
Cadmium Nitrate	11	5.74
Uranyl Nitrate	12.5	6.31
Iron(ic) Nitrate	12	6.01
Rubidium Nitrate	10.5	5.43
Indium Nitrate	11	5.60
Dysprosium Nitrate	12	7.06
Samarium Nitrate	12	6.33
Gallium Nitrate	10.5	5.89
Scandium Nitrate	11	5.82
Rhodium Nitrate	10	5.18
Gadolinium Nitrate	11.5	5.86
Yttrium Nitrate	14	7.34

TABLE II

ANION DOPANT

Dopant	Average Burning Time	Average Relative Candlepower
Sodium Carbonate	11	5.27
" Peroxide	17	7.57
" Iodide	11	6.56
" Acetate	12	6.64
" Fluoride	12	6.78
" Oxalate	12	6.16
" Phosphate	13	6.76
" Sulfite	13.5	7.32
" Bromide	11.5	6.11
" Thiosulfate	11	5.74
" Nitrite	11	5.33
" Sulfate	11	5.65
" Borate	19	8.31
" Perchlorate	12	6.51
" Chloride	10.5	5.37
" Chlorate	11.5	6.08
" Dichromate	12	6.31
" Chromate	10	5.89
" Iodate	10.5	5.29
" Thiocyanate	10.5	5.57
" Permanganate	12	5.54
" Formate	13	6.98
" Hypochlorite	10.5	5.89
" Sulfide	13	6.62

TABLE III

CATION-ANION DOPANT

Dopant	Average Burning Time	Average Relative Candlepower
Antimony Trichloride	11	5.75
Arsenic Trioxide	11	5.92
Uranyl Acetate	11	5.65
Antimony Trichloride	13	6.59
Ruther'um Tetraoxide	11	5.58
Boric Acid	12.5	7.00
Silica	10.5	5.94
Rhenium Trichloride	10	5.65
Selenium Dioxide	12	6.02
Germanium Diiodide	11	5.41
Zirconium Sulfate	8.5	4.95
Osmium Trichloride	10.5	4.46
Erbium Sulfate	12.5	6.59
Vanadium Tribromide	13.5	6.17
Stannic Chloride	14.5	8.02
Gold Chloride	9	5.19
Iridium Triiodide	10	5.91
Praseodymium Sulfate	10	5.10
Tungsten Hexachloride	11.5	5.38
Sodium Meta Perisdate	13	6.93
Platinum Chloride	12	6.46

FIGURE I

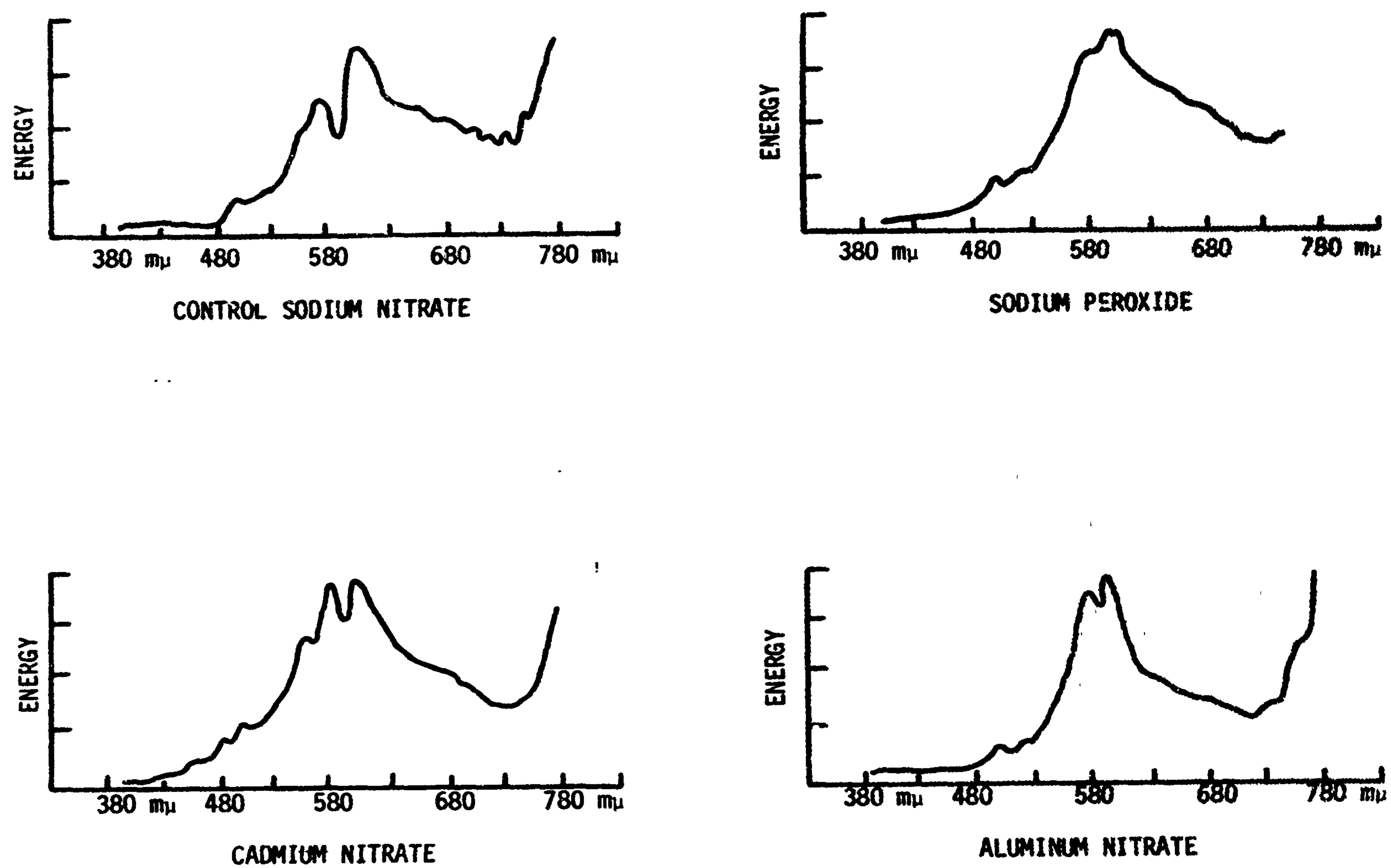
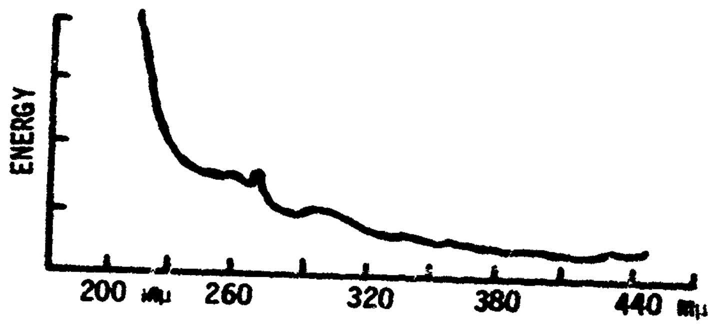

ENERGY
380 mμ
480
580
680
780 mμ
CONTROL SODIUM NITRATE
ENERGY
380 mμ
480
580
680
780 mμ
SODIUM PEROXIDE
ENERGY
380 mμ
480
580
680
780 mμ
CADMIUM NITRATE
ENERGY
380 mμ
480
580
680
780 mμ
ALUMINUM NITRATE

FIGURE II



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Sodium nitrate was "doped" with 75 contaminants. The "doped" sodium nitrate was then used to prepare miniature magnesium-sodium nitrate candles. Data was obtained on burning time, relative candlepower output and spectral distribution of the energy radiated over the region from 200 mμ to 780 mμ. Evaluation of the data indicates that some dopants have advantageous effects upon the magnesium-sodium nitrate system.

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